National Aeronautics and Space Administration

EARTH'S BRIDGE TO SPACE

LSP

LAUNCH SERVICES PROGRAM

There's a reason challenging endeavors are called "ROCKET SCIENCE"

TABLE OF CONTENTS

INTRODUCTION

NASA's Launch Services Program (LSP) unites scientific and robotic spacecraft customers' needs with the appropriate rocket, managing the process to ensure the spacecraft is placed in orbit around the Earth, the Sun, or powered to destinations deeper into the solar system. LSP assists customers who need specialized, highly technical support worldwide, and enables some of NASA's greatest scientific missions and technical achievements.

Let's take three minutes to explore LSP as "Earth's Bridge to Space."

NASA's Launch Services Program: The Common Thread

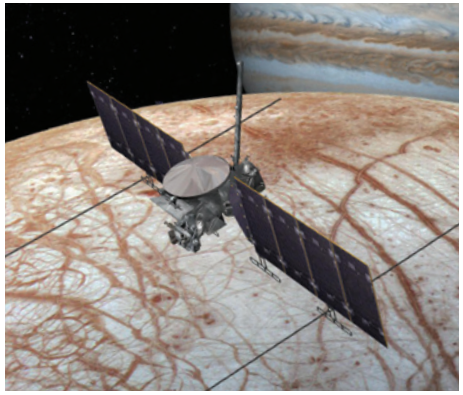
Watch this introductory video here:
https://www.youtube.com/watch?v=9GwU8O8wfpQ

OBJECTIVE

This portfolio is intended to educate and connect you to some of NASA's most significant science-based missions, and to highlight the contributions made by LSP. By increasing your understanding of LSP's contributions to NASA's mission success, you may also realize the benefits to you and all of humankind.

ROCKET SCIENCE 411

What is a Spacecraft?



A spacecraft, also referred to as a payload, is a machine designed to fly in space. Generally a type of satellite, spacecraft are used for a variety of purposes, including communications, Earth observation, meteorology, navigation, planetary exploration, and transport of humans and cargo. Every spacecraft is unique to the specific mission and has different destination requirements. To carry out its scientific mission, a spacecraft relies on a launch vehicle to transport it to the proper orbit.

What is a Launch Vehicle?

A launch vehicle is a rocket-propelled vehicle used to carry a spacecraft from Earth's surface to space, usually to Earth orbit or beyond. Although launch vehicles may appear similar, no two are alike because they are extremely complex devices with millions of pieces and systems that must be calculated and constructed to work together. A launch vehicle is chosen based on the spacecraft's mission requirements. For example, the farther away from Earth the spacecraft needs to go, the bigger and more powerful the launch vehicle needs to be.

The spacecraft and launch vehicle must be compatible. Every mission presents its own set of unique complexities. The energy required to reach orbit and the unforgiving nature of small errors is the reason we refer to challenging endeavors as "rocket science."

- **Each spacecraft has a specific destination in space**, which could be a unique orbit or even another planet. There could even be a specific time the satellite must reach its orbital destination, as is the case for planetary missions since planets are moving targets. This could be compared to a quarterback in a football game, who has to analyze and calculate how to throw a ball to a moving receiver. The quarterback must account for the speed of the ball, the arc of the throw, and the timing of the throw in order to reach the moving target at the right time and place. In this comparison, LSP and the commercial launch vehicle provider are the quarterback, the spacecraft is the football, and the destination requirement is the receiver.

- **The launch vehicle and spacecraft must also survive ground handling and launch environments.** This includes stressful environments such as vibration, contamination, electromagnetic, thermal, and structural loads along the way. For example, consider the vibration felt during takeoff when flying in an airplane. It's also important for the launch vehicle and spacecraft to be controlled in a clean environment at the proper temperatures, and to be protected from external environments such as lightning. Also, during flight, rockets are subjected to forces of weight, thrust, and aerodynamics, which each bring their own challenges.

For more info and educational opportunities visit:
https://public.ksc.nasa.gov/LSPEducation

LSP STRATEGY

Origin and Purpose

In 1998, NASA's Launch Services Program (LSP) was established to support NASA's science and robotic missions by procuring commercial launch vehicles. The program was established at NASA's Kennedy Space Center to centralize technical and management support to spacecraft customers. LSP brings together people, procurement, engineering best practices, strategic planning, studies, and cutting-edge techniques—all instrumental components for the United States to have a dependable and secure Earth-to-space bridge that is dedicated to launching all types of spacecraft.

The principal objectives of LSP are to provide **safe, reliable, cost-effective** and **on-schedule** launch services to including mission analysis, spacecraft integration, and processing for payloads seeking transportation to space on commercial launch vehicles. LSP acts as a broker, matching spacecraft with optimal launch vehicles. Once the correct vehicle is selected, LSP buys that spacecraft a ride to space and works to ensure mission success by managing the overall process and assuring the rocket will work correctly to deliver a healthy spacecraft to the correct orbit or destination. LSP provides support throughout the journey, **from pre-mission planning to the post-launch phase** of the spacecraft.

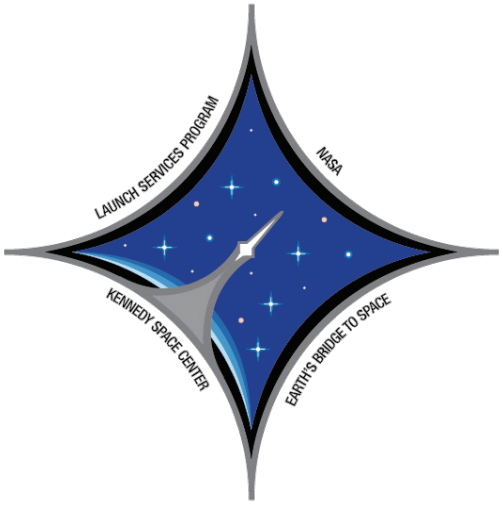
As such, LSP provides NASA's acquisition and program management of commercial launch vehicles missions. This is accomplished through a skillful NASA/contractor team providing leadership, expertise, and cost-effective services in the commercial launch arena to satisfy space transportation requirements and maximize the probability of mission success.

Launch Services Program has launched nearly 100 missions to date.
The work of LSP is considered **Earth's bridge to space!**

Vision and Mission

Vision:
Science and discovery through unlimited access to the universe

Mission:
Uniting customers, capabilities, and culture to explore space through unparalleled launch services



FUN FACT:

Did you know LSP's establishment year of '98 is written in the stars? Much is revealed in the LSP logo, which depicts the following:

- There are nine stars to the left of the rocket and eight stars to the right of the rocket, which represents 1998, the year the program began.
- The compass star represents LSP's direction and leadership in launch services.
- The four points represent LSP's four strategic goals.
- The rocket in the center represents the fleet of vehicles used for launch services.
- The trail connecting the rocket to Earth is representative of the LSP motto "Earth's Bridge to Space."

LAUNCH SERVICES

There are many pieces that make up the "big picture" of Launch Services Program. The services that LSP provides are based on the spacecraft customer's mission requirements. Represented here are LSP's primary "end-to-end" services, from advanced planning through post launch. LSP also offers tailored approaches to serve a wide variety of customers, including one-of-a-kind launch contracts and advisory services.

Advanced Planning

- Supports spacecraft design
- Conducts launch vehicle trade studies

Business

- Procures commercial launch services, payload processing facilities, and support contractors
- Manages multi-year budgets from the spacecraft customer for specific missions, and from NASA's Human Exploration Operations Mission Directorate for infrastructure aspects of LSP

Technical

- Provides insight and approval of launch vehicle fleets
- Verifies and validates mission engineering and analysis
- Certifies launch systems
- Integrates spacecraft to launch vehicles

Launch Site Operations

- Supports spacecraft standalone testing, propellant loading, payload encapsulation, and integrated testing in a clean facility
- Provides infrastructure to communicate with spacecraft

Launch Operations

- Provides communications and telemetry data
- Participates in countdown
- Gives "go for launch"
- Ensures liftoff and orbital insertion through separation

10 9 8 7 6 5 4 3 2 1

Post Launch

- Determines mission success
- Reviews and assesses data

LAUNCH SITES

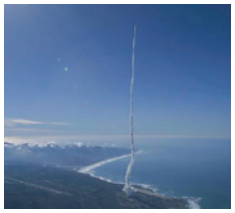
Location, Location, Location

The physical location of the launch facility is another important consideration in space science. The decision on the proper launch site location is based on the **type of science**, and what **orbital destination** the satellite needs to reach to gather the science.

The primary launch sites for NASA are **Cape Canaveral Air Force Station** in Florida, and **Vandenberg Air Force Base** in California.

Cape Canaveral Air Force Station, Florida

- Located adjacent to Kennedy Space Center, Cape Canaveral Air Force Station is ideal for spacecraft requiring a west-east orbit. Missions requiring **equatorial orbits** are typically launched from this location due to its closer proximity to the equator.



Vandenberg Air Force Base, California

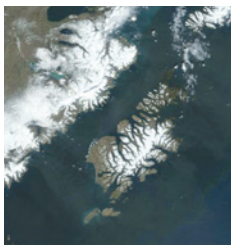
- Located between Los Angeles and San Francisco, Vandenberg Air Force Base is preferred for spacecraft requiring a north-south orbit, and is best for missions requiring **polar orbits**.

Wallops Island Flight Facility, Virginia

- Located on the eastern shore of Virginia is NASA's Goddard Space Flight Center, the principal facility for **suborbital** research programs and launch of Northrop Grumman's Antares launch vehicle for International Space Station resupply missions.

Reagan Test Site, Kwajalein Atoll, Republic of the Marshall Islands

- Located midway between Hawaii and Australia lies Kwajalein, the world's largest coral atoll. Reagan Test Site has been used for missions requiring **equatorial orbits** and low inclinations.

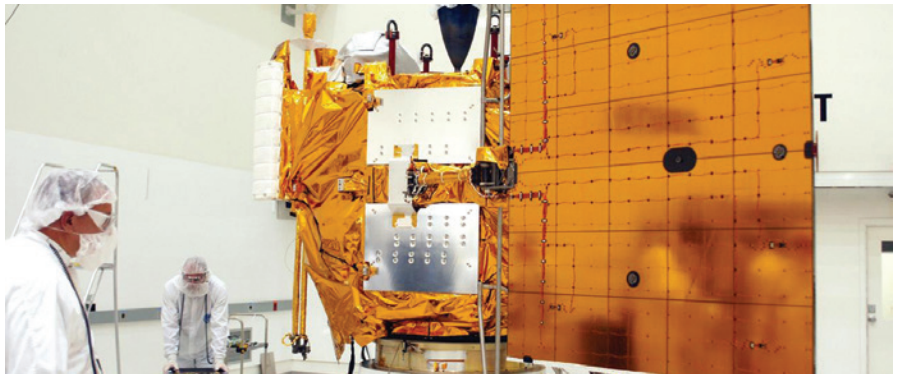


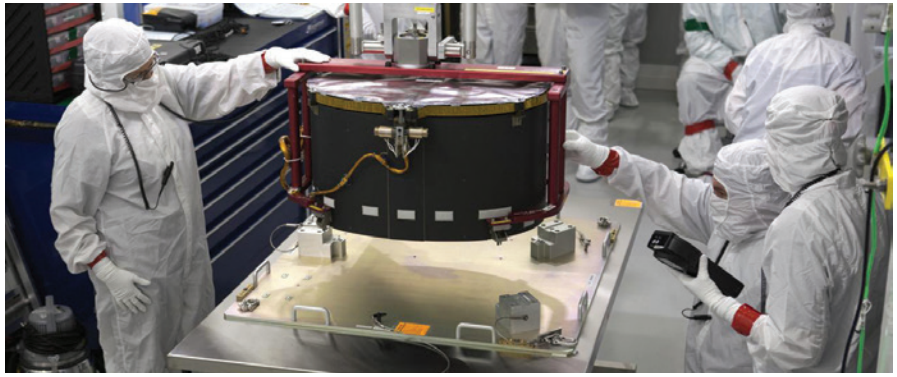
Kodiak Island, Alaska

- Located off the southern coast of Alaska is Kodiak Island, one of the best locations in the world for **polar launch operations**. Kodiak Island provides a wide launch azimuth and an unobstructed downrange flight path.

SPACECRAFT CUSTOMERS

The work performed by NASA's Launch Services Program (LSP) is entirely focused on the spacecraft customer's mission needs. In other words, the work of LSP benefits the customer's goals, which ultimately **benefits society through the legacy of scientific discovery!** Listed on the right are just some of LSP's spacecraft customers.



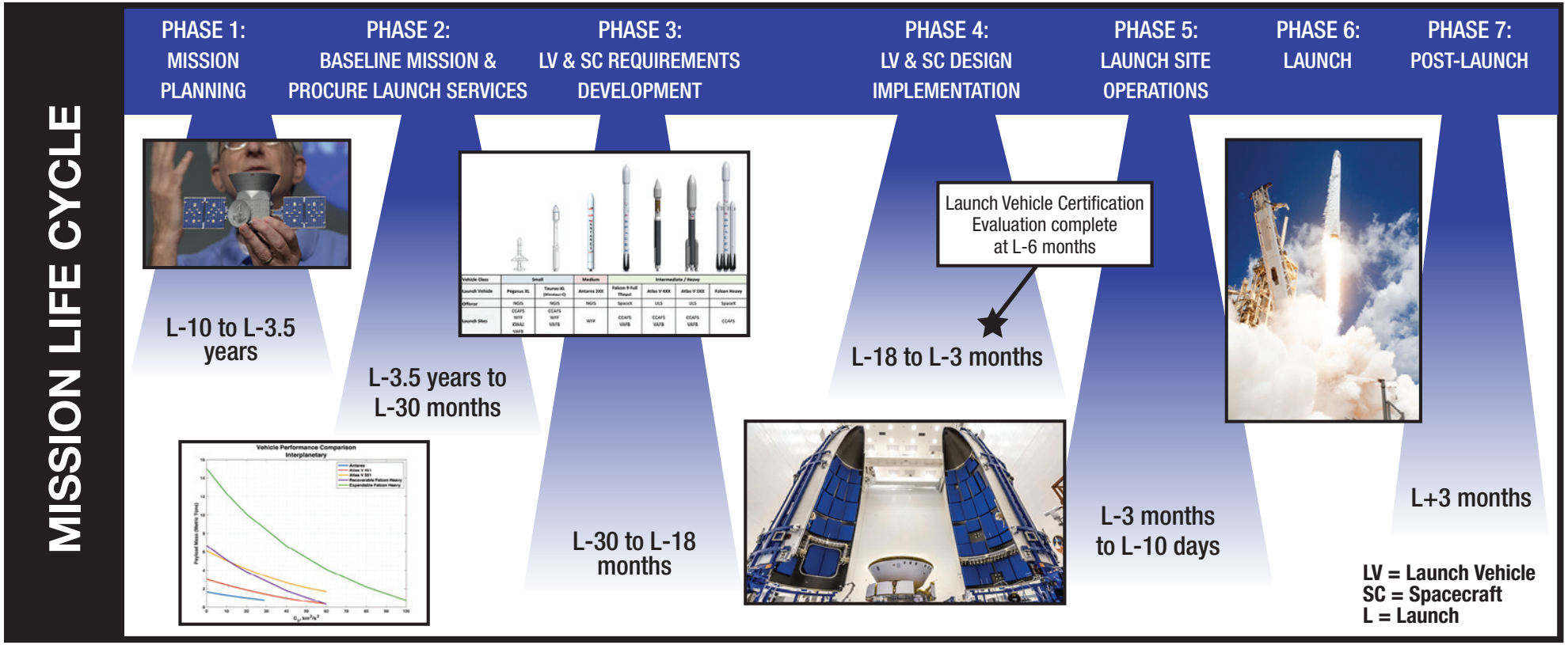


- **NASA Centers**
  - Ames Research Center in Silicon Valley, California
  - Goddard Space Flight Center in Greenbelt, Maryland
  - Glenn Research Center in Cleveland, Ohio
  - Jet Propulsion Laboratory at the California Institute of Technology
  - Johnson Space Center in Houston, Texas
  - Langley Research Center in Hampton, Virginia
  - Marshall Space Flight Center in Huntsville, Alabama
- **Applied Physics Laboratory** in Laurel, Maryland
- **MIT Lincoln Laboratory** in Lexington, Massachusetts
- **Southwest Research Institute** in San Antonio, Texas
- Universities and High Schools across the United States launching small research satellites (CubeSats)
- **International Partners**
  - European Space Agency (ESA)
  - Indian Space Research Organization (ISRO)
  - Japan Aerospace Exploration Agency (JAXA)
- **Other Government Agencies** (customers and collaborators):
  - United States Space Force (USSF)
  - National Reconnaissance Organization (NRO)
  - National Oceanic and Atmospheric Administration (NOAA)

MISSION LIFE CYCLE

For traditional primary satellites to be launched, the process from mission selection to launch can take anywhere from 4-10 years. The reason for this is primarily due to the vast complexities and risk levels of developing the specific spacecraft. The depiction below shows the support that LSP provides as the spacecraft is being conceived until well after the spacecraft has launched. This is what comprises end-to-end full service.

LSP also offers tailored approaches for a wide variety of customers, including one-of-a-kind contracts and advisory services. These services vary in scope, complexity, and duration based on the spacecraft customer's needs. Generally, mission requirements that are lower in complexity and risk would warrant a reduction in time and cost. An example of this tailored approach would be CubeSat missions using the Venture Class Launch Services (VCLS) contract.



PHASE 1
Support the SC mission design with launch service information, and refine SC customer requirements

PHASE 2
Establish/initiate a Launch Service contract and identify all funding and resources required

PHASE 3
Develop launch services requirements and preliminary design, and support SC build and integration

PHASE 4
Implement launch services requirements; and support SC build, integration, and test phase

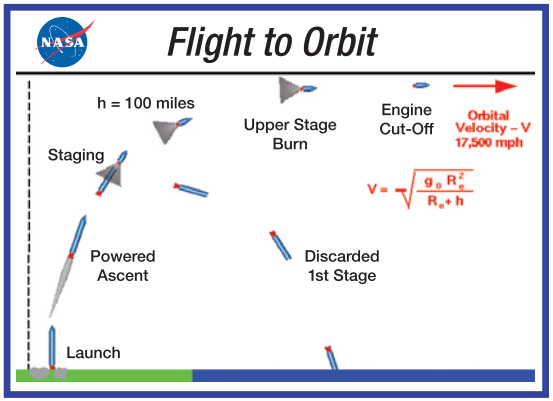
PHASE 5
Final test and check out of LV and SC systems

PHASE 6
Integrate SC to LV and test, and launch to place SC in proper orbit

PHASE 7
Mission Success! Verify LV performance, and identify issues to be resolved

LAUNCH VEHICLES

Expendable launch vehicles all use the same basic technology to get off the pad and into space: two or more rocket-powered stages, which fall away when their engine burns are completed, as pictured to the right.



Reusable launch vehicles allow for recovery of part of the launch system for later use. Whatever the customer puts on top of the final discarded stage is considered the payload or spacecraft.

When we talk about how Earth and planets travel around the Sun, we say they orbit the Sun. Likewise, satellites also orbit Earth. There are multiple orbits to choose from, and different launch vehicles to get them there - all determined by the purpose of the mission.

- **Low-Earth Orbit** is between 100 and 1,242 miles (160 and 2,000 km) above the earth. This is the lowest-energy orbit to reach, and is where the International Space Station resides. Satellites travel approximately 17,000 miles per hour to stay in low-Earth Orbit. At that speed, you could get from NASA's Kennedy Space Center to Orlando in about 13 seconds. Satellites with an orbital path over or near the poles maintain a polar orbit, which is usually in low-Earth Orbit.
- **Medium-Earth Orbit** is between 1,242 and 22,236 miles (2,000 and 35,786 km) above Earth.
- **Geosynchronous Orbit** is from 22,236 miles (35,786 km) above the earth. Satellites headed for GEO first go to an elliptical orbit with an apogee of about 23,000 miles (37,015 km). Firing of the spacecraft's engines at apogee then makes the orbit round.

LSP Launch Vehicle Fleet

Vehicle Class	Small		Medium	Intermediate / Heavy			
Launch Vehicle	Pegasus XL	Taurus-XL (Minotaur-C)	Antares 2XX	Falcon 9 Full Thrust	Atlas V 4XX	Atlas V 5XX	Falcon Heavy
Offeror	NGIS	NGIS	NGIS	SpaceX	ULS	ULS	SpaceX
Launch Sites	CCAFS WFF KWAJ VAFB	CCAFS WFF VAFB	WFF	CCAFS VAFB	CCAFS VAFB	CCAFS VAFB	CCAFS

LSP offers a **mixed-fleet approach** to support science, Earth-orbit and interplanetary missions under the contractual mechanism known as NASA Launch Services (NLS) II. This provides multiple types of vehicles, ensuring the optimal launch vehicle is chosen to support the spacecraft's mission requirements, and to ensure competitive prices prevail among the launch vehicle providers. Generally speaking, missions with smaller satellites use smaller, less expensive vehicles, and the larger flagship missions utilize the larger, higher performance, and more demonstrated vehicles. This could be compared to the purchase of an automobile, where various vehicle classes ranging from a compact car to a full-size pickup truck meet diverse requirements and budgets.

Pictured above is the current NLS II fleet of launch vehicles that are used to launch spacecraft into low-Earth orbit or deep space missions - **all possessing unique capabilities**. The NLS II contract offers the option to on-ramp new launch vehicles each year. There are new rockets being developed that have not yet demonstrated a reliable track record, and LSP enables buying them for risk tolerant customers on unique one of a kind contracts. LSP also offers unique "one-off" contracting approaches for customers that need additional options that are not offered with NLS II.

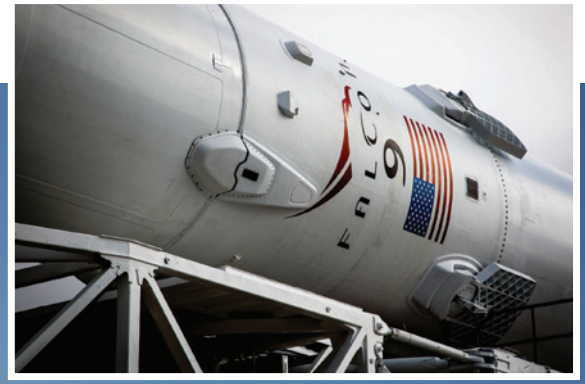
LAUNCH VEHICLE PROVIDERS AND CAPABILITIES

Falcon 9

SpaceX produces multiple configurations of their Falcon launch vehicles. Falcon 9, the world's first commercial orbital class reusable rocket, is a two-stage rocket designed and manufactured by SpaceX for the reliable and safe transport of people and payloads. Reusability allows SpaceX to refly the most expensive parts of the rocket, which in turn drives down the cost of space access. Falcon 9 is capable of carrying payloads weighing up to 50,265 lbs (22,800 kg) into low-Earth orbit, up to 18,300 lbs (8,300 kg) into geostationary transfer orbit, and up to 8,860 lbs (4,020 kg) to Mars.

SPACEX

Learn more about Falcon 9: spacex.com/vehicles/falcon-9



Falcon Heavy

Falcon Heavy is the most powerful operational rocket in the world by a factor of two. Falcon Heavy is composed of three Falcon 9 nine-engine cores whose 27 Merlin engines together generate more than 5 million pounds of thrust at liftoff, equal to approximately eighteen 747 aircraft. Falcon Heavy is capable of carrying payloads weighing up to 140,660 lbs (63,800 kg) into low-Earth orbit, up to 58,860 lbs (26,700 kg) into geostationary transfer orbit, and up to 37,040 lbs (16,800 kg) to Mars.

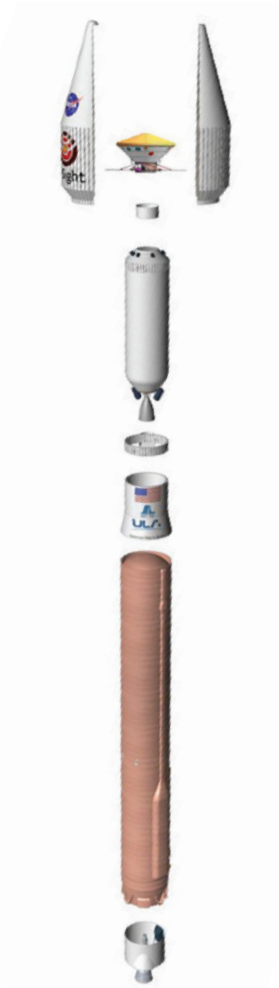
Learn more about Falcon Heavy: spacex.com/vehicles/falcon-heavy

FUN FACT: To put payload weights into perspective, the average U.S. car weighs 4,000 lbs and a school bus weighs 29,000 lbs. Our launch vehicle providers are doing some heavy lifting!

LAUNCH VEHICLE PROVIDERS AND CAPABILITIES

Atlas V 400 Series

United Launch Alliance (ULA) offers multiple configurations of the Atlas V rocket. To carry payloads, the 400 series has a fairing of four meters in diameter which is available in three different lengths. Up to three solid rocket boosters can be added to increase its performance. The Atlas V 400 series can carry a payload weighing up to 33,660 lbs (15,260 kg) to low-Earth orbit, and up to 16,970 lbs (7,700 kg) into geostationary transfer orbit.



Atlas V 500 Series

The Atlas V 500 series has a fairing of five meters in diameter (which also comes in three different lengths) to carry much larger payloads into orbit. This fairing volume is greater than an average single-family home. The Atlas V 500 series can carry a payload weighing up to 41,570 lbs (18,850 kg) to low-Earth orbit, and up to 19,620 lbs (8,900 kg) into geostationary transfer orbit. Up to five solid rocket boosters can be added to increase its performance.

To learn more about Atlas V and its many configurations, visit:
ulalaunch.com/rockets/atlas-v

To identify the specific configuration of the Atlas V 400 and 500 series, a three-digit (XYZ) naming convention is used to identify (1) the payload fairing size; (2) the number of solid rocket boosters; and (3) the number of Centaur engines.

LAUNCH VEHICLE PROVIDERS AND CAPABILITIES

Pegasus XL

Northrop Grumman Innovation Systems (NGIS) produces the Pegasus XL, a small expendable rocket that attaches beneath the company's Stargazer L-1011 aircraft. Approximately 40,000 feet over open ocean the Pegasus XL is released and free-falls for five seconds before igniting its first stage rocket motor. It is the only airborne-launched rocket. The three-stage Pegasus rocket is used to deploy small satellites weighing up to 1,000 lbs (453.59 kg) into low-Earth orbit. This patented air-launch system provides customers flexibility in launch location and requires minimal ground support.

Learn more about Pegasus XL:
northropgrumman.com/space/pegasus-rocket

Antares

Northrop Grumman's Antares rocket is a two-stage vehicle that provides low-Earth orbit launch capability for payloads weighing up to 17,636 lbs (8,000 kg). An optional third stage allows for higher orbits and planetary missions. The Antares design utilizes powerful RD-181 first stage engines and is primarily used to support the company's Commercial Resupply Services contract with NASA.

Learn more about Antares:
northropgrumman.com/space/antares-rocket

Minotaur-C (Taurus XL)

Minotaur Commercial (Minotaur-C), formerly known as Taurus XL, is a four-stage solid fueled launch vehicle built by Northrop Grumman. Minotaur-C is based on the air-launched Pegasus rocket, substituting the carrier aircraft for a powerful solid rocket motor to carry the vehicle away from the ground. Minotaur-C is able to carry a maximum payload of 3,214 lbs (1,458 kg) into a low-Earth orbit.

Learn more about Minotaur-C:
northropgrumman.com/space/minotaur-rocket

SMALL SATELLITE MISSIONS

As part of the mixed-fleet approach supporting the spacecraft customer's mission requirements, Launch Services Program also manages the launch of small satellite missions, known as CubeSats, which are selected by **NASA's CubeSat Launch Initiative (CSLI)**.

- CSLI provides access to space for small satellites developed by the NASA Centers and programs, educational institutions, and non-profit organizations. This gives CubeSat developers access to a low-cost pathway to conduct research in the areas of science, exploration, technology development, education, or operations.
- By providing a progression of educational opportunities including CSLI for students, teachers, and faculty, NASA assists the nation in attracting and retaining students in Science, Technology, Engineering, and Mathematics (STEM) disciplines.
- CSLI also promotes and develops innovative technology partnerships among NASA, U.S. industry, and other sectors for the benefit of agency programs and projects. NASA thus gains a mechanism to use CubeSats for low-cost technology development or pathfinders.
- CubeSats, also called nanosatellites, come in several sizes and are based on the standard CubeSat "unit," measuring 10x10x10cm or 1U (small enough to fit in the palm of your hand). CSLI launches CubeSats as small as 1U and as large as 12U.

- Due to the small size of CubeSats and the amount of research they can complete once in orbit, NASA can make room for them on the same rockets that take much larger payloads into space. In these instances, the CubeSats are essentially "hitchhiking" to space and are considered secondary payloads to the primary satellites being launched.
- Launch Services Program finds these rides to space for CSLI selected CubeSats by manifesting them on NASA, military, or commercial launch vehicles going to the right orbit in the right timeframe. The complement of CSLI CubeSats on a given flight is referred to as an **Educational Launch of Nanosatellites (ELaNa) mission**.
- Once manifested, LSP works with both the CubeSat developer and the launch service provider to ensure that technical, safety, and regulatory requirements are satisfied before launch.

For more information and videos on NASA's historical and upcoming small satellite missions visit:
nasa.gov/directorates/heo/home/CubeSats_initiative

SMALL SATELLITE MISSIONS

Venture Class Launch Services (VCLS)

Many new companies are designing relatively small rockets with the promise to lower launch costs. Under NASA's VCLS contract, LSP is using CubeSat missions to demonstrate their capability and build relationships with this new part of the U.S. industry. VCLS offers faster launch services than traditional launch services for primary missions. This is because smaller satellites are more agile, flexible, and affordable, thereby warranting a higher risk tolerance and reduced requirement for insight and approval.

VCLS was born out of LSP's desire to expand our customers' launch options by demonstrating contracting flexibility

The current launch vehicles under the contractual mechanism of VCLS are pictured to the right. The future of small class vehicles is one to watch, as it is anticipated that the number of small class launch vehicles will increase in number, thereby further reducing costs.

Watch "Venture Class Rockets: First Class Flights for CubeSats" to see what VCLS is all about and how CubeSats are transitioning from secondary "hitchhikers" into primary payloads.

https://www.youtube.com/watch?v=0EJqfWMuOAQ

Electron

Rocket Lab's Electron launch vehicle has a height of 55.8 ft (17 meters), with a diameter of 3.9 ft (1.2 meters), and has 2 stages. It can carry a maximum payload weighing 496 lbs (225 kg).

Additional information on Electron is on Rocket Lab's website at: rocketlabusa.com/electron/

LauncherOne

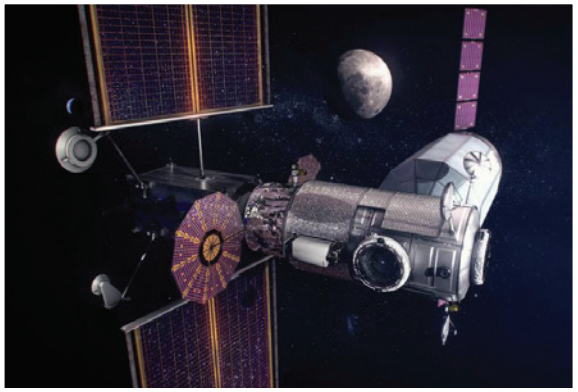
Virgin Orbit's LauncherOne is an expendable, two-stage launch vehicle. It is capable of carrying a payload of up to 661 lbs (300 kg) into orbit, and 1,102 lbs (500 kg) into low-Earth Orbit.

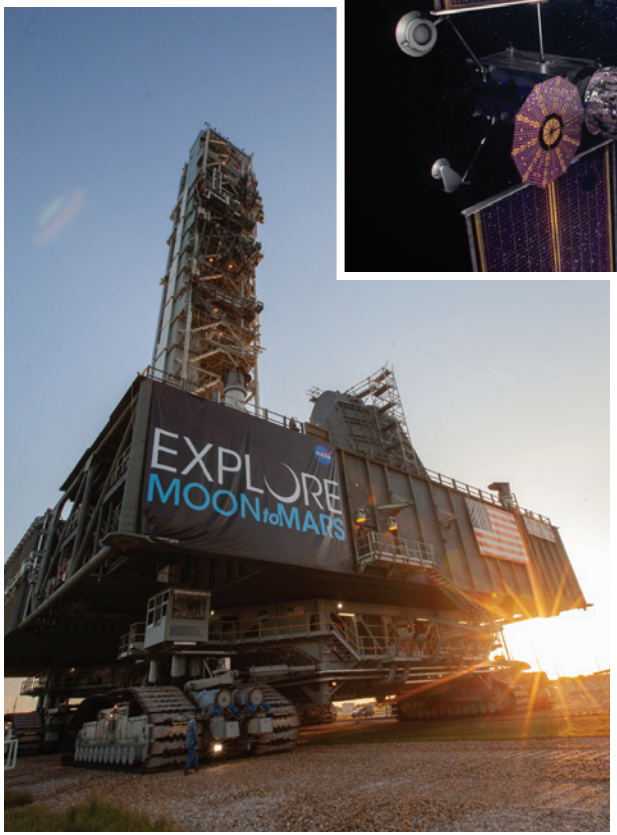
Additional information on LauncherOne is on Virgin Orbit's website at: virginorbit.com/

ADVISORY ROLE MISSIONS

Artemis Program & The Gateway

The Launch Services Program supports NASA's return to the Moon. For NASA's Artemis architecture, LSP is serving in a major consulting role for the Gateway Logistics Element, the Human Landing System, the Habitation and Logistics Outpost, and the Power and Propulsion Element, as well as providing mission management to deliver the Canadian Deep Space Exploration Robotic (DSXR) System to the Gateway. LSP is also leveraging expertise in the Venture Class Launch Services (VCLS) and has contracted for the launch of CAPSTONE, a precursor lunar CubeSat mission, to reduce technical risk in advance of crewed Artemis campaigns.





Commercial Crew Program & Commercial Resupply Services

LSP also provides advisory expertise for Commercial Crew Program (CCP) missions and Commercial Resupply Services (CRS) program missions in support of the International Space Station. LSP supports CCP and CRS on an as-needed basis by giving insight into the launch vehicles and assessments on certain aspects by request depending on the details of the mission. So far, LSP has provided advisory services for more than 30 CRS missions launched on SpaceX's Falcon 9 and Northrop Grumman's Antares rockets. LSP also provides advisory services for SpaceX and Boeing CCP current and future missions.

PARTNERSHIPS AND COLLABORATION

The reach of Launch Services Program is far and wide. LSP is able to successfully carry out its mission with the support of numerous NASA programs/centers, Department of Defense, commercial providers, foreign governments, start-ups, and more.

Space exploration and scientific discovery is a team effort.
LSP is partnered with innovative aerospace and technology companies from all over the world. Below are all of the companies currently awarded LSP-managed contracts.

January 19
2006

New Horizons

New Horizons launched on a ULA Atlas V rocket from Space Launch Complex 41 at Cape Canaveral Air Force Station on January 19, 2006. It swung past Jupiter for a gravity boost and scientific studies in February 2007, and conducted a six-month-long reconnaissance flyby study of Pluto and its moons in the summer of 2015. **The New Horizons mission was to examine Pluto's and Charon's global geology and geomorphology, map their surface compositions and temperatures, and examine Pluto's complex atmosphere.** As part of an extended mission in 2019, the spacecraft headed further into the Kuiper Belt to examine another of the ancient, icy mini-worlds
in that vast region, at least a billion miles beyond Neptune's orbit. The mission is currently extended through 2021 to explore additional Kuiper Belt objects.

The Johns Hopkins University Applied Physics Laboratory (APL) designed, built, and operates the New Horizons spacecraft and manages the mission for NASA's Science Mission Directorate. A close-up look at these worlds from a spacecraft promises to tell an incredible story about the origins and outskirts of our solar system. New Horizons is exploring – for the first time – how ice dwarf planets like Pluto and Kuiper Belt bodies have evolved over time.

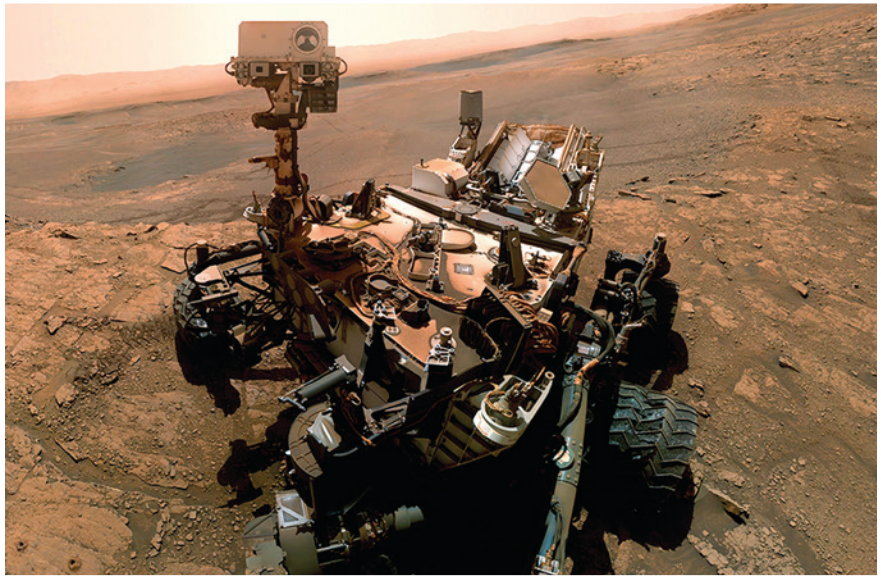
To see more of the incredible images captured by New Horizons, visit:

https://www.nasa.gov/mission_pages/newhorizons/images/

HISTORICAL MISSION HIGHLIGHTS

November 26
2011

Mars Science Laboratory (MSL) - Curiosity



NASA's Curiosity rover launched aboard a ULA Atlas V rocket from Space Launch Complex 41 at Cape Canaveral Air Force Station on November 26, 2011. The rover landed on Mars on August 6, 2012. **Curiosity was designed to assess whether Mars ever had an environment able to support small life forms,** called microbes. Its mission is to determine the planet's habitability. Curiosity has ten science instruments designed to search for signs of life, including methane, to help determine if the gas is from a biological or geological source. Curiosity is currently still operational. The rover has traveled over 14 miles and has taken almost 700,000 photographs.

Experience Curiosity through this interactive experience to learn about the rover and its adventures in the Pahrump Hills region of Gale Crater.

https://eyes.nasa.gov/curiosity/

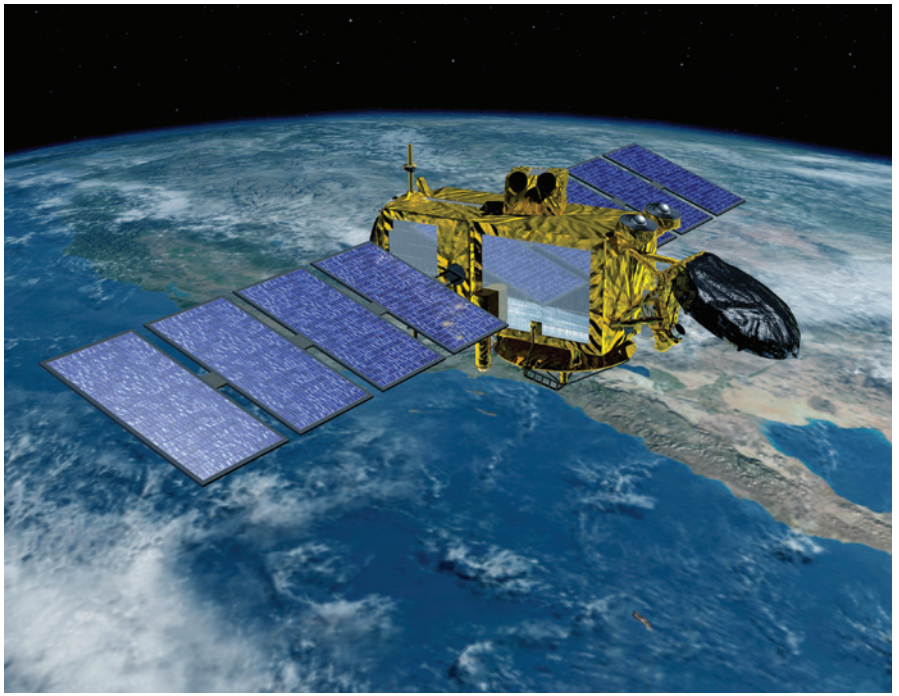
Want more on Mars?
VIDEO: Mars in a Minute: How Do You Get to Mars?
youtube.com/watch?v=-nAhag_iFx0

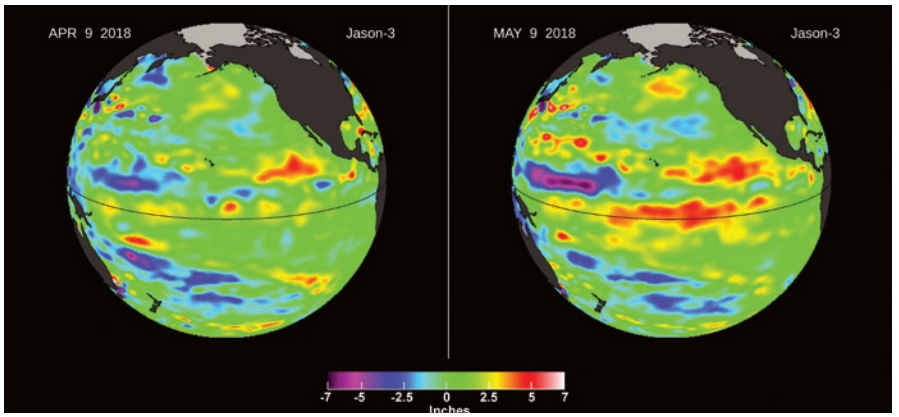
January 17
2016

Joint Altimetry Satellite Oceanography Network-3 (Jason-3)

Jason-3 lifted off from Space Launch Complex 4E at Vandenberg Air Force Base in California on January 17, 2016 aboard a SpaceX Falcon 9 rocket. It is the fourth mission in the U.S.-European series of satellites that measure the height of the ocean surface. The mission will **improve weather, climate, and ocean forecasts,** including helping NOAA's National Weather Service and other global weather and environmental agencies more **accurately forecast the strength of tropical cyclones.**

The mission extended the time series of ocean surface topography measurements begun by the TOPEX/Poseidon satellite mission in 1992, continuing through the Jason-1 mission launched in 2001 to the currently operations OSTM/Jason-2 mission launched in 2008.



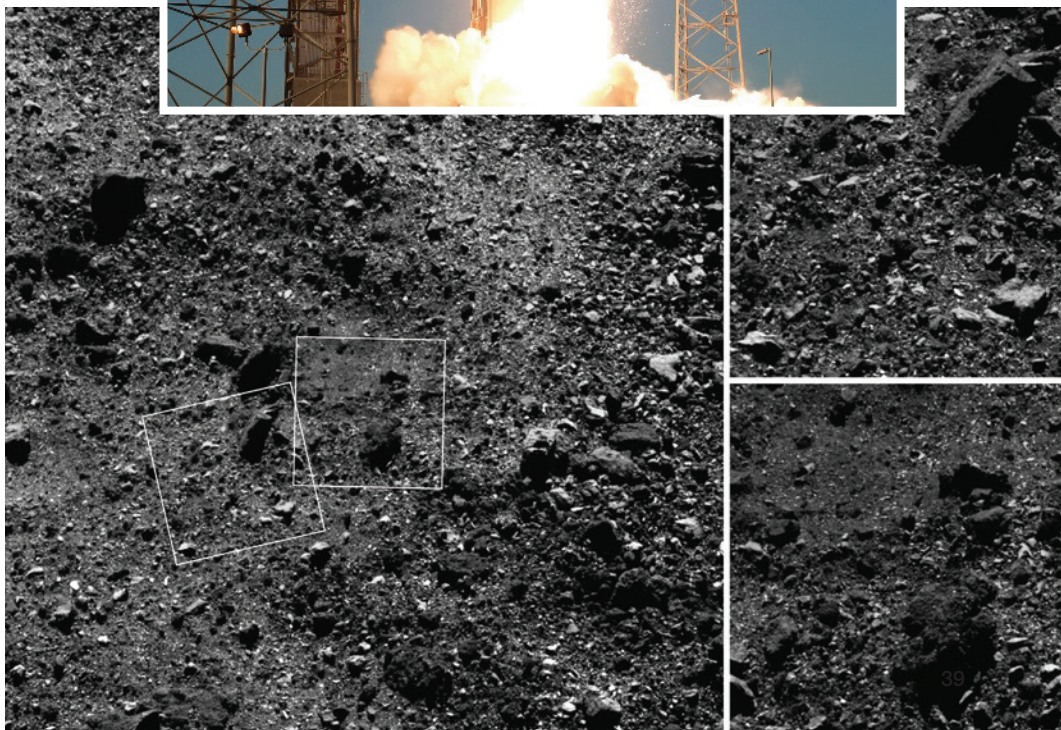


Jason-3 has begun mapping the ocean! This shows sea surface height (blue/magenta indicates lower-than-normal sea levels, while yellow/red indicates higher-than-normal sea levels). Data from Jason-3 will be used to monitor climate change and track phenomena like El Niños.

September 8
2016

Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-REx)

OSIRIS-REx, NASA's first asteroid sampling mission, launched from Space Launch Complex 41 at Cape Canaveral Air Force Station atop a ULA Atlas V rocket on September 8, 2016, for a seven-year mission to and from near-Earth asteroid Bennu. This was the beginning of a journey that could revolutionize our understanding of the early solar system. **The OSIRIS-REx mission is to map Bennu's surface using 3D laser imaging, retrieve samples from the surface, and return to Earth.** The mission will help scientists investigate how planets formed and how life began, as well as improve our understanding of asteroids that could impact Earth. The spacecraft completed its 1.2 billion-mile journey and arrived at asteroid Bennu in December of 2018. OSIRIS-REx is scheduled to return the sample to Earth in 2023.



HISTORICAL MISSION HIGHLIGHTS

April 18
2018

Transitioning Exoplanet Survey Satellite (TESS)

NASA's newest planet hunter, TESS, is the next step in the search for planets outside of our solar system, including those that could support life. The mission will survey the entire sky over the course of two years and will **analyze 200,000 of the brightest stars near the Sun to search for transiting exoplanets**. TESS launched on April 18, 2018, aboard a SpaceX Falcon 9 rocket from Cape Canaveral Air Force Station. During its first year of science, TESS discovered 21 planets outside of our solar system.

TESS scientists expect the mission will catalog more than 2,000 planet candidates and vastly increase the current number of known exoplanets. Of these, approximately 300 are expected to be Earth-sized and super-Earth-sized exoplanets, which are worlds no larger than twice the size of Earth. TESS will find the most promising exoplanets orbiting our nearest and brightest stars, **giving future researchers a rich set of new targets for more comprehensive follow-up studies**. The prime mission ended July 2020, with an extended mission following shortly after.

FUN FACT: 100 light-years away, in our own Milky Way galaxy, in the constellation Dorado, sits a planetary system named TOI 700. It is home to TOI 700 d, the first Earth-size habitable-zone planet discovered by TESS.

To keep up with the latest TESS stories, visit:
nasa.gov/content/latest-tess-stories

August 12
2018

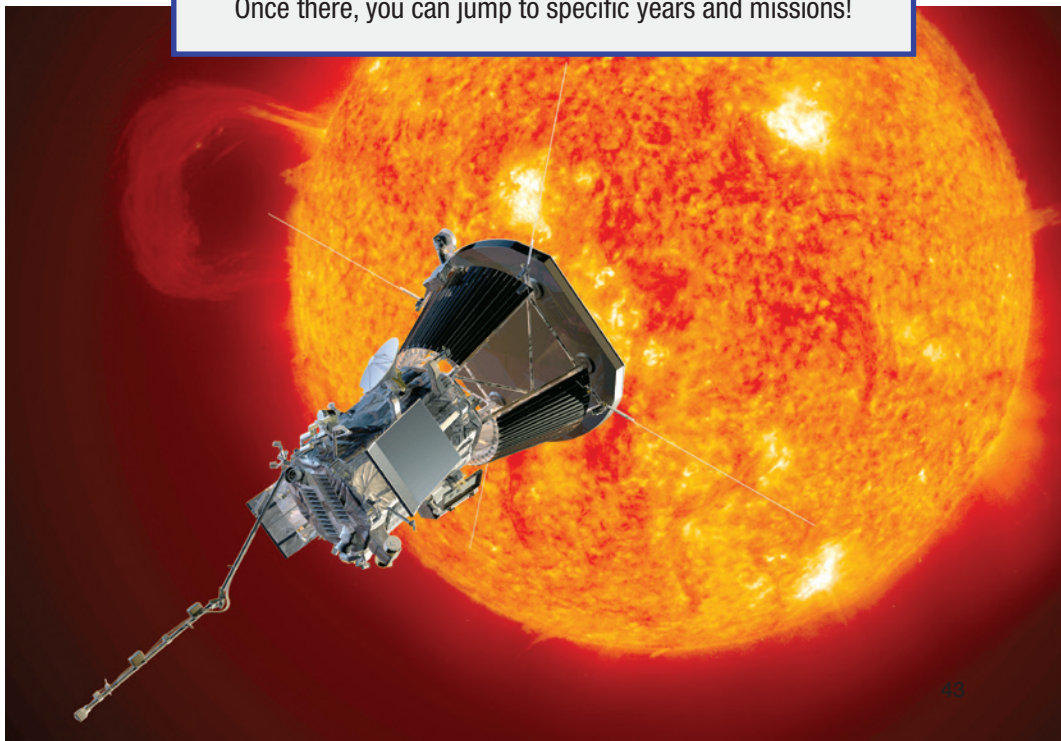
Parker Solar Probe

NASA's Parker Solar Probe launched aboard a ULA Delta IV Heavy rocket on August 12, 2018, from Space Launch Complex 37 at Cape Canaveral Air Force Station and will be the **first-ever mission to "touch" the Sun**. The spacecraft will travel directly into the Sun's atmosphere about 4 million miles from our star's surface. NASA's historic Parker Solar Probe mission will revolutionize our understanding of the Sun, where changing conditions can propagate out into the solar system, affecting Earth and other worlds. Parker Solar Probe will travel closer to the Sun's surface than any spacecraft before it, **facing brutal heat and radiation conditions**–and ultimately providing humanity with the closest-ever observations of a star.

On June 9, 2020, NASA's Parker Solar Probe signaled the success of its fifth close pass by the Sun, called a perihelion, with a radio beacon tone. The spacecraft completed the fifth perihelion flying within 11.6 million miles from the Sun's surface and reaching a top speed of about 244,225 miles per hour. **This sets the record for closest human-made object to the Sun and fastest human-made object.**

To learn more about LSP's historical launches, visit:
public.ksc.nasa.gov/lsphistory

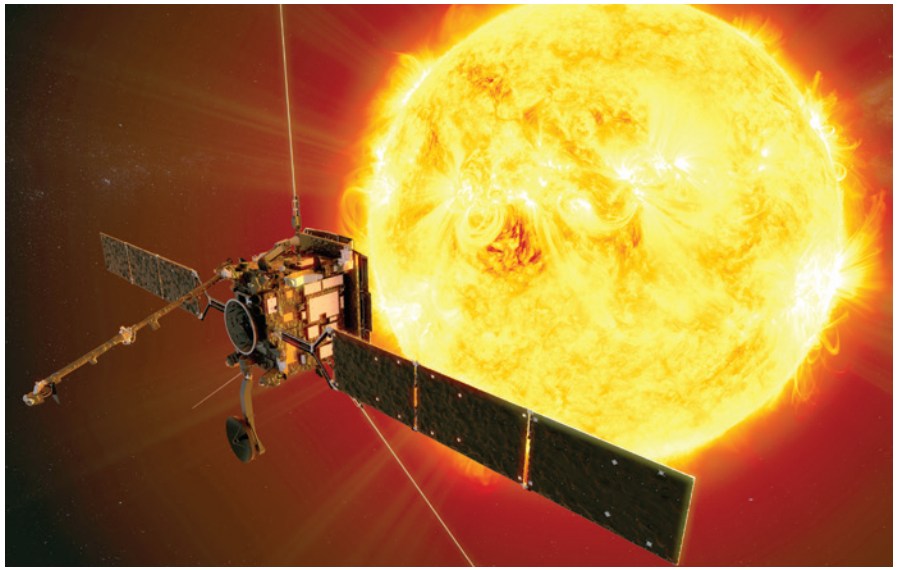
Once there, you can jump to specific years and missions!



IN THE LAUNCH QUEUE FOR 2020-2021

Solar Orbiter

Less than two years after Parker Solar Probe was launched, Solar Orbiter, an international cooperative mission between the European Space Agency (ESA) and NASA, is also headed to study the Sun. Solar Orbiter will travel as close as 26 million miles from the Sun, inside the orbit of Mercury. There, it will **measure the magnetic fields, waves, energetic particles, and plasma escaping the Sun** while they are in their pristine state. Solar Orbiter operators will use the gravity of Venus to gradually shift the spacecraft's orbit. These flyby maneuvers will enable Solar Orbiter to get the first ever proper view of the Sun's poles. Studying the activity in the polar regions will help scientists to better understand the behavior of the Sun's magnetic field, which drives the creation of the solar wind that in turn affects the environment of the entire solar system.

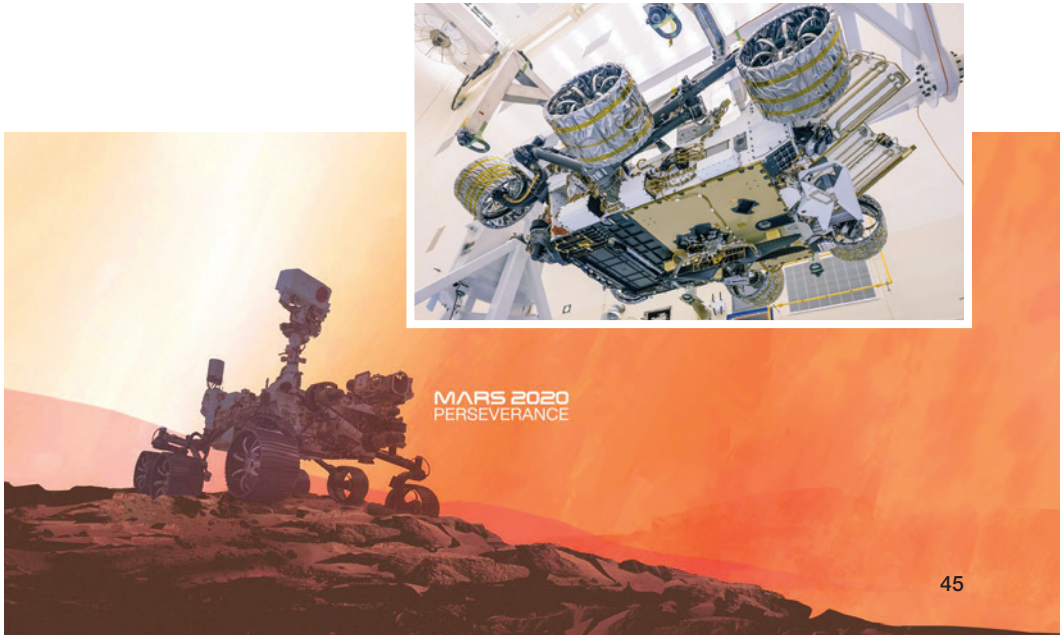


Solar Orbiter successfully launched from Space Launch Complex 41 at Cape Canaveral Air Force Station on an Atlas V rocket on February 10, 2020 and will make its first close approach to the Sun mid-June of 2020. The images taken by Solar Orbiter, to be released in mid-July, will be the **closest images of the Sun ever captured**.

Mars 2020

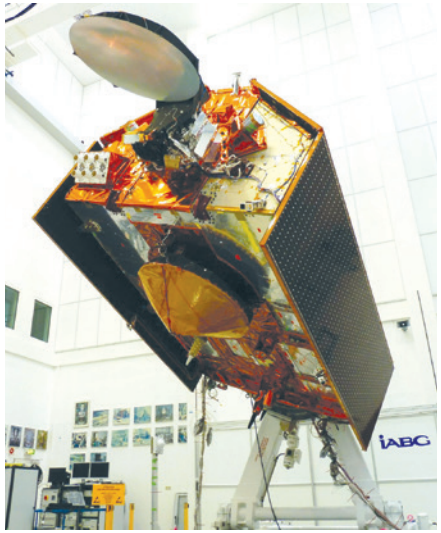
The Mars 2020 mission is part of NASA's Mars Exploration Program, a long-term effort of robotic exploration of the Red Planet. The Mars 2020 mission addresses high-priority science goals, including **determining whether life ever existed on Mars, characterizing the planet's climate and geology, and preparing for future human exploration**. The Perseverance rover introduces a drill that can collect core samples of the most promising rocks and soils and set them aside for a future mission that could potentially return these samples to Earth. The Perseverance rover is joined by Ingenuity, a small helicopter that will be the first ever technological demonstration of testing powered flight on Mars.

The mission also provides opportunities to gather knowledge and demonstrate technologies that address the challenges of future human expeditions. These include testing a method for producing oxygen from the Martian atmosphere, identifying other resources (such as subsurface water), improving landing techniques, and characterizing weather, dust, and other potential environmental conditions that could affect **future astronauts living and working on Mars**.



IN THE LAUNCH QUEUE FOR 2020-2021

Sentinel-6 Michael Freilich



Sentinel-6 Michael Freilich (Sentinel 6) will observe and record global sea level changes, **a key component to understanding how Earth's climate is changing**. This mission will be joined by an identical satellite slated to launch in 2025 for a total of ten years of targeted observations. A secondary objective of the mission will be to measure temperature and humidity in the troposphere, the atmospheric layer in which we live. Sentinel 6 has the **potential for large societal impact worldwide** as it supports applications in the area of operational oceanography, including ship routing, support for offshore and other marine industries, fisheries, and responses to environmental hazards.

This key ocean observation satellite was named in honor of Earth scientist Michael Freilich, who retired in 2019 as head of NASA's Earth Science division, a position he held since 2006.

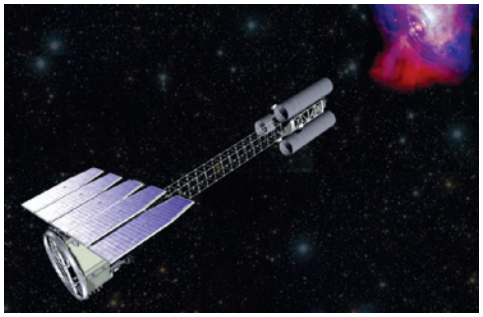
Landsat 9

Landsat 9, a partnership between NASA and the U.S. Geological Survey, will continue the Landsat program's critical role in **monitoring, understanding, and managing the land resources needed to sustain human life**. Landsat is the only U.S. satellite system designed and operated to repeatedly observe the global land surface at a moderate scale that shows both natural and human-induced change.

Landsat 9, like Landsat 8, will have a higher imaging capacity than past Landsats, allowing more valuable data to be added to the Landsat's global land archive. Landsat 9 will enable **informed decision support for key areas** such as tropical deforestation, urban expansion, water use, coral reef degradation, glacier and ice shelf retreat, natural and human-made disasters, and climate change.

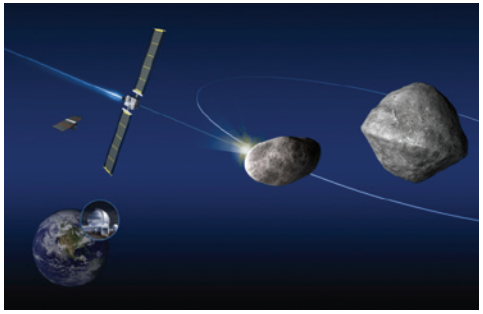
IN THE LAUNCH QUEUE FOR 2020-2021

Imaging X-ray Polarimetry Explorer (IXPE)



IXPE will exploit the polarization state of light from astrophysical sources to **provide insight into our understanding of X-ray production** in objects such as neutron stars and super-massive black holes. During IXPE's two-year mission, targets such as active galactic nuclei, microquasars, pulsars and pulsar wind nebulae, magnetars, accreting X-ray binaries, supernova remnants, and the galactic center will be studied.

Double Asteroid Redirection Test (DART)



The DART mission is a planetary defense-driven test of technology for preventing an impact of Earth by a hazardous asteroid. DART will be the first demonstration of the kinetic impactor technique to **change the motion of an asteroid in space**. The binary near-Earth asteroid Didymos's secondary body (or "moonlet") is the target. The DART spacecraft will achieve the kinetic impact deflection by deliberately crashing itself into the moonlet with the aid of an onboard camera and autonomous navigation software. The collision will change the speed of the moonlet in its orbit around the main body by a fraction of one percent, but this will change the orbital period of the moonlet by several minutes — enough to be observed and measured using telescopes on Earth.

Lucy

Lucy will be the first mission to explore the small bodies known as Trojans, the outer solar system asteroids that orbit the Sun at the same distance as Jupiter. The gas giant normally scatters away all asteroids in its vicinity, but due to the combined gravitational influences of the Sun and Jupiter, these Trojan asteroids have been trapped on stable orbits for billions of years. These Trojans provide a **unique, never-before-explored sample of the remnants of our early solar system**. Lucy will carry out remote sensing on six Trojan asteroids to address surface color/composition, interiors/bulk properties, and any satellites/rings.

Geostationary Operational Environmental Satellite-T (GOES-T)

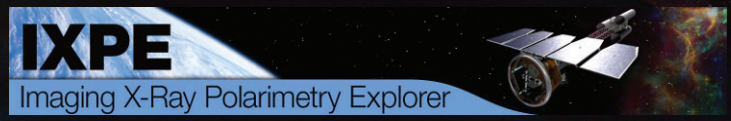
The GOES-T mission will provide **advanced imagery and atmospheric measurements** of Earth's weather, oceans, and environment. The mission will also provide real-time mapping of total lightning activity and improved monitoring of solar activity and space weather. GOES-T is the third spacecraft in the next generation GOES-R Series of geostationary weather satellites operated by NOAA. These satellites circle the Earth in a geosynchronous orbit, meaning they orbit Earth's equatorial plane at the same speed of Earth's rotation. This allows them to stay in a fixed position in the sky in respect to a point on the ground. GOES satellites continually view the Western Hemisphere from approximately 22,300 miles above Earth.

IN THE LAUNCH QUEUE FOR 2020-2021

LSP

NASA's
Launch Services Program

2020-2021



KNOWLEDGE LAUNCH

Now that you have broadened your knowledge of "rocket science" and the work of NASA's Launch Services Program, here are some final questions to see just how much you've launched your learning. **Good luck!**

1) What year was the LSP established?
    a. 2001
    b. 1998
    c. 1995

2) True or False: LSP's job is to act like a broker, matching spacecraft with launch vehicles and manage the service to ensure mission success.

3) True or False: LSP's two primary launch sites are Cape Canaveral Air Force Station (CCAFS) in Florida and Vandenberg Air Force Base (VAFB) in California. Other launch locations are NASA's Wallops Flight Facility in Virginia, the Kwajalein Atoll in the South Pacific's Republic of the Marshall Islands, and Kodiak Island in Alaska.

4) On average, how long does it take to go from mission selection to launch (end-to-end)?
    a. Between 4-10 years
    b. Between 1-5 years
    c. Between 9-15 years

5) How long did it take from launch for the "Curiosity" rover to land on Mars?
    a. 5 hours
    b. 9 months
    c. 2 years

6) True or False: A satellite must travel fast, at a speed of approximately 17,000 miles per hour, to remain in low-Earth Orbit.

7) How do small satellite missions, CubeSats, compare to traditional/primary satellite missions?
    a. CubeSats are the same as primary satellites.
    b. CubeSats are tiny in size and low in cost, and help engineers, researchers, and students conduct science in a host of fields. CubeSat missions also assume lower risk levels, and have lower insight and approval, and therefore are faster to launch.

8) What primary factors are considered when deciding the proper launch site location?
    a. The decision is based on which launch site is available.
    b. The decision is based on knowing the type of science needed, and where the orbital destination of the satellite will need to reach in order to accomplish the science.

9) True or False: LSP offers every commercial launch vehicle built by a U.S. company by a competition on the appropriate contract mechanism that ensures the spacecraft mission requirements will be met.

10) True or False: The Launch Services Program has launched nearly 100 missions to date.

Answers: 1.B; 2. True; 3. True; 4. a; 5. b; 6. True; 7. b; 8. b.; 9. True; 10. True

To learn more about NASA and how NASA technologies benefit life on Earth visit: **https://www.nasa.gov/specials/nasaathome/** for a collection of e-books, podcasts, videos, and other at-home activities.

There's more space in your life than you may realize!

STAYING CONNECTED TO LSP

Like us on Facebook:
NASA's Launch Services Program

Follow us on Twitter:
@NASA_LSP

Check out the LSP playlist on YouTube:
Launch Services Program

For more information, check out our website!
Launch Services Program

Be sure to check out these additional sub-menus on our website for fun and interesting articles, videos, fact sheets, activities, and more!

- LSP News and Features
  (nasa.gov/content/lsp-news-and-features)
- T-Zero Documentaries
  (nasa.gov/content/launch-services-program-t-zero-documentaries)
- Missions A-Z
  (nasa.gov/missions)
- Hangar AE
  (nasa.gov/sites/default/files/atoms/files/hangarae_2017factsheet_508_hr.pdf)
- LSP: Cool Stuff
  (nasa.gov/content/launch-services-program-cool-stuff)

National Aeronautics and Space Administration

John F. Kennedy Space Center
Kennedy Space Center, FL 32899

www.nasa.gov

SP-2020-10-957-KSC